



**University
of Victoria**

Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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**“Quantitative Techniques for Permanent Breast Seed
Implant Brachytherapy”**

Department of Physics and Astronomy

Friday, September 8, 2017
12:00 P.M.
Clearihue Building
Room B017

Supervisory Committee:

Dr. Andrew Jirasek, Department of Physics and Astronomy, University of Victoria (Co-Supervisor)
Dr. Wayne Beckham, Department of Physics and Astronomy, UVic (Co-Supervisor)
Dr. Michelle Hilts, Department of Physics and Astronomy, UVic (Member)
Dr. Nikolai Dechev, Department of Mechanical Engineering, Uvic (Outside Member)

External Examiner:

Dr. Kathleen Surry, Department of Physics and Engineering, University of Western Ontario

Chair of Oral Examination:

Dr. Karen Courtney, School of Health Information Science, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

Permanent breast seed implant brachytherapy (PBSI) is a recently developed form of treatment for early-stage breast cancer which can be completed in a single day procedure. Due to the reduced treatment burden, PBSI has the potential to benefit many women. However the technique has not been widely implemented, potentially related to the lack of a standardized, reproducible procedure and a high level of operator dependence. Challenges relating to target visualization uncertainties and the reliance on free-hand 2D ultrasound (US) guidance potentially inhibit adoption of the technique. This work aims to evaluate the current PBSI procedure to identify uncertainties and potential sources of errors in the current technique and develop methods to ameliorate these issues to potentially increase treatment accuracy, standardize the procedure, and reduce user-dependence.

A comprehensive assessment of the current PBSI procedure was performed to identify any trends or systematic errors in the placement of seeds and establish the effects of seed placement accuracy on the treatment. Baseline seed placement accuracy, assessed in a 20 patient cohort was observed to be 9 ± 5 mm. Random displacements of seeds from their planned position contributed significantly to the overall accuracy. No trends or systematic errors were observed across the aggregate population, however intra-patient systematic offsets were observed. The potential effects of visualization of the post-lumpectomy cavity (seroma) on treatment delivery was investigated using spatially registered CT and 3DUS images. Planning the treatment on CT, as is standard practice, resulted in less than optimal coverage to target volumes defined on US in the majority of cases. The effects of intra-operative adjustments relating to the visualization differences on the two modalities was assessed by shifting the CTbased treatment plan to centre on the US-defined seroma. Such shifts were shown to potentially contribute to the systematic displacements observed in PBSI delivery, and also had significant dosimetric effects on the planned target volumes.

The impact of seroma visualization on PBSI implant accuracy was further assessed through the evaluation of CT and 3DUS images acquired for PBSI patients. Correlations were observed between the seed placement accuracy and the inter-user variability of seroma definition on CT ($r = 0.74$, $p = 0.01$) and the volume difference of the seroma on the two modalities ($r = 0.65$, $p = 0.04$), indicating that discrepancies in target delineation can impact treatment accuracy. The systematic displacements of the implants were observed to be correlated with the visualization metrics, however random displacements were independent of seroma delineation.

Deviations in needle positioning during insertion may not be realized until the implant is complete, thus contributing to the random inaccuracies in seed placement. A purpose built 3DUS scanning system was investigated for its use in guiding needle insertion. Registration of the treatment template with the imaging system was validated to provide accurate target localization for needle insertion. Adjustments and re-insertion of needles under 3DUS guidance provided significant improvements to the needle positioning accuracy. A simulated implant with the guidance system indicated that overall treatment accuracy may be improved through the clinical implementation of such a system.

Efforts to improve seroma definition during treatment planning and image guidance during the delivery can significantly increase seed placement accuracy and reduce the need for subjective intra-operative adjustments to the setup and needle positioning. Standardization of such advanced imaging techniques can greatly benefit the PBSI procedure by reducing user dependence and help to promote implementation.